[초 청]

The rotating disc gauge for measurement of high vacuum - a review of recent work

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Introduction The rotating disc gauge (RDG) was originally developed by Dushman (1915) as an instrument for total pressure measurement in high vacuum. Its potential was not exploited until the application of contemporary technology in work by the authors which began in 1989. Construction and characterisation of, and results using an RDG are discussed.

Experimental and theory The RDG measures the molecular torque induced in a stationary silicon 'receiver' disc (radius R = 46 mm) by a matching coaxial and parallel high frequency (f = 0-833 Hz) 'sender' disc which is a small distance away, see Figure 1. The receiver is held by a fibre of torsion constant $c = 1.47 \times 10^{-7}$ Nm. Molecules leave the sender with an imposed tangential velocity according to the Knudsen cosine distribution (represented by the circle C). At low pressures the resultant molecular torque causes the receiver to rotate. Rotation is measured as the deflection y_o (mm) of a light spot deflection on a screen at a distance L = 1088 mm. The governing equation[1] is

$$P_{RDG} = \left(\varepsilon\, \sigma\, 2\pi f R^4 \left(\frac{\pi M}{8 R_o T} \right)^{1/2} \right)^{-1} \frac{c}{2L}\, y_o$$

$\varepsilon = \varepsilon(t,R)$ is the edge effect factor[2] for molecules leaving the discs' interspace ($\varepsilon = 0.83$ at t = 4.3 mm), T the temperature, R_O the gas constant and σ is the tangential momentum accommodation coefficient of molecules on the receiver surface. A ±3% uncertainty in pressure measurements is attainable.

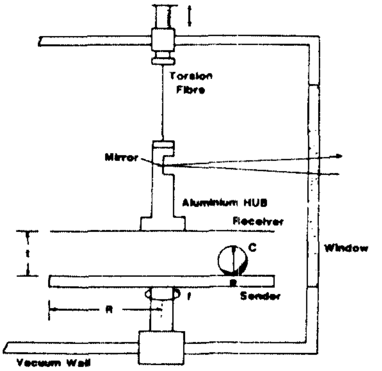

Figure 1 Essential features of the RDG apparatus

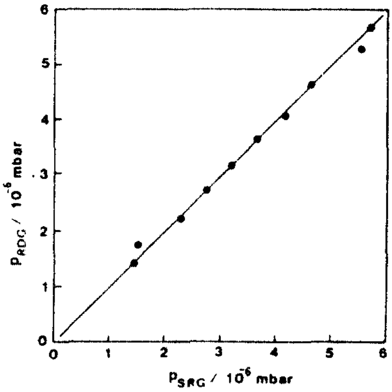

Figure 2 P_{RDG} versus P_{SRG}

Results and discussion Figure 2 shows good agreement between pressure measured with the RDG (assuming $\sigma = 1$) and a spinning rotor gauge (P_{SRG}) in experiments using nitrogen. Table 1 lists σ values determined for various gases and receiver surfaces[2]. For a smooth, gas-covered surface the value of σ is expected to be unity; on roughened surfaces the normal momentum component effectively contributes to the tangential component so that $\sigma > 1$. Figure 3 shows P_{RDG} versus P_{SRG} into the transitional flow regime[3] where the level of agreement is reduced, possibly due to the effects of slip.

Gas	σ Smooth silicon	 Rough silicon	 Titanium on silicon
Hydrogen	1.02±0.12	1.04±0.09	1.05±0.08
Helium	0.99±0.04	1.00±0.06	1.00±0.08
Methane	0.99±0.03		
Water vapour	0.99±0.04	1.02±0.05	1.06±0.05
Nitrogen	0.99±0.02	1.01±0.05	1.02±0.05
Air	0.95±0.05	1.04±0.05	1.04±0.05
Carbon dioxide	0.99±0.03		
Krypton	0.95±0.04		

Table 1 Measured tangential momentum accommodation coefficients

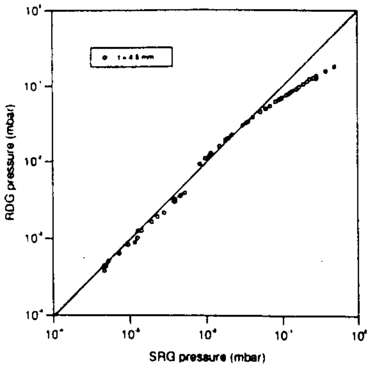

Figure 3 P_{RDG} versus P_{SRG} in molecular and transitional flow

High temperature superconductor (HTS) bearing The sensitivity of the fibre suspension limits measurements to about 10^{-7} mbar. Another RDG was developed[4] in which suspension of the receiver takes place by the attractive force between a permanent magnet attached to it and a LN_2 cooled $YBa_2Cu_3O_7$ pellet held outside the vacuum chamber. This HTS bearing provides a means for continuous measurement whereby molecular torque accelerates the receiver suspension (of moment of inertia I). Internal losses though give rise to a residual drag torque (offset) G_D in the HTS bearing which was evaluated by measuring receiver deceleration. Figure 4 shows the effect of residual pressure on deceleration $-\dot{\omega}$; there is linearity in ultra high vacuum where molecular drag is negligible and $G_D = -I\dot{\omega}$(typically 9 × 10^{-9} Nm). Improvements in HTS pellet (A-B-C) grain structure reduced the residual drag, as is shown in Figure 5. The apparatus has been developed as, potentially, a standard method for the measurement of intrinsic drag torques. Determination of the offset drag torque allows acceleration measurements to be used to measure ultra high vacuum pressures.

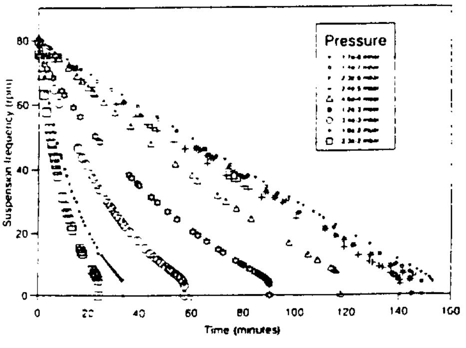

Figure 4 HTS bearing suspension deceleration at various pressures

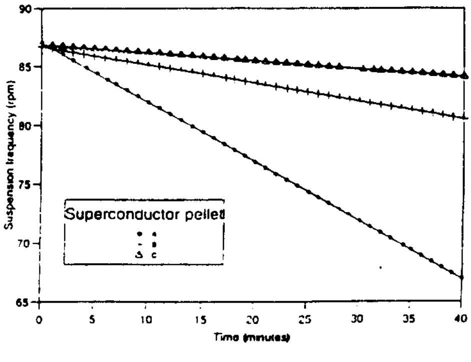

Figure 5 Reduction in deceleration and drag torque for improved pellet structure in the HTS bearing

[1]A.Chambers, A.D. Chew and A.P. Troup, *J. Vac. Sci. Technol. A*, **10**, 2655 (1992).
[2]A.D. Chew, A.Chambers and A. P. Troup, *Vacuum*, **44**, 583 (1993).
[3]A.D. Chew, A.Chambers, G.J. Pert, S.L. Bastow and A.P. Troup, *Vacuum*, **46**, 773 (1995).
[4]A.D. Chew, A.Chambers and A.P. Troup, *Applied Superconductivity*, **2**, in press (1995).